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USAFSAM MICROPROCESSOR AUDIOMETER: SYSTEM REFERENCE MANUAL

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NOTICES

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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A microprocessor audiometer was designed and built by USAFSAM personnel to investigate new techniques in audiometry and hearing conservation. The system's primary function is to provide a flexible test bed for developing new audiogram algorithms and implementing hearing-conservation decision criteria. Pertinent information regarding hardware and software implementation is provided.

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INTRODUCTION

During the past 30 years, the Air Force Hearing Conservation Program (HCP) has been instrumental in reducing the amount of noise-induced hearing loss in Air Force personnel. Enhancements to this program have shown the need for a new audiometric instrument capable of eliminating three existing problems: (1) audiometric test technique inconsistency--due to the variety of types and models of audiometers in use and the many technicians involved; (2) technician error--centering around improper decision making based on the reference audiogram and subsequent significant-threshold-shift determination; and (3) massive data processing--resulting from the requirement that all HCP audiograms be made in duplicate, with one copy going to the individual's medical record and the other to Brooks AFB, Texas, for inclusion in the Hearing Conservation Data Registry.

Because of these problems, a microprocessor audiometer (MPA) was designed and built at the USAF School of Aerospace Medicine (USAFSAM) to validate the appropriateness of such an instrument (see Fig. 1) in the HCP. The purpose of

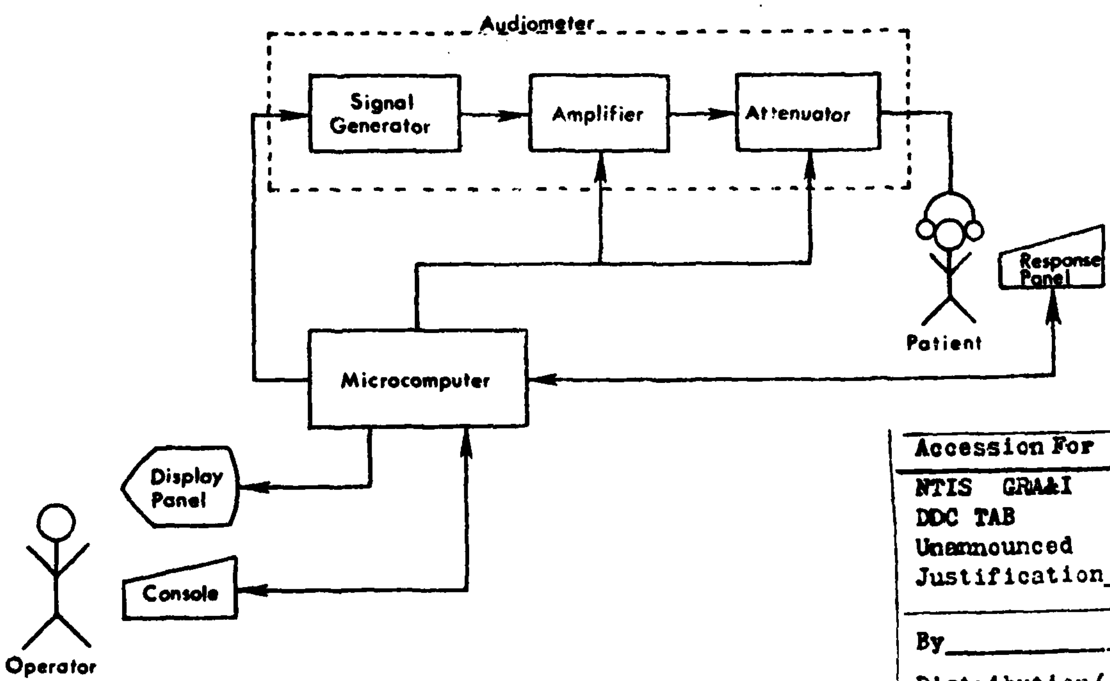


Figure 1. MPA system: block diagram.

this report is to sufficiently describe the MPA so that it can be maintained and improved as requirements change. Schematics and cable diagrams have been included as an appendix, for easy reference.

SYSTEM DESCRIPTION

As with any microcomputer-controlled system, the two major elements are hardware and software. For the USAFSAM MPA, the hardware (Fig. 1) consists of a microcomputer, analog audiometer, response panel, console, and display panel. Each of these elements will be briefly described, starting with the microcomputer.

As indicated in Figure 2, the microcomputer consists of the following Intel multibus compatible boards: SBC 80/20 single-board computer, SBC 104 input/output memory board, and SBC 416 programmable read-only memory (PROM) board. These components were used because their flexibility and capability met all requirements of the USAFSAM MPA. The microcomputer serves two primary functions: (1) to provide the intelligence needed to communicate with the operator, and (2) to provide all control functions for the analog audiometer.

Since the analog audiometer receives all of its control commands from the microcomputer, the audiometer's sole function is to generate the proper tones during the test. As shown in Figure 1, the audiometer consists of a signal generator, amplifier, and attenuator. The audio signals are sent to the patient, who closes the loop by responding to what is heard; then the response panel provides the necessary feedback to the microcomputer for further processing of the audiometric test. Additionally, as the examination progresses, continuous test results are provided to the operator via the display panel. The data displayed include the current hearing threshold level (HTL), the ear and frequency selected, and the presence/absence of the tone stimulus. All data are displayed via light-emitting diodes (LEDs), as shown in Figure 3.

The SAM MPA has a hierarchical software structure (Fig. 4), with the WIZARD (operating system) and AUDIO (applications software) modules providing the top-level support. WIZARD [3,4] is a microcomputer-oriented operating system designed at USAFSAM for use on all Intel 8080 microprocessor-based systems. It provides a virtual system for handling all high-level peripheral input/output (I/O) and a monitor for use in bench-level debugging.

The AUDIO module initiates all actions concerned with the audiometric test. It provides a general purpose command-decoder system which can be modified to include any new commands needed as well as any additional action routines. Note in Figure 4 that the WIZARD and the AUDIO modules have equal accessibility to the various software and hardware elements. However, all communications with the console device are routed through WIZARD.

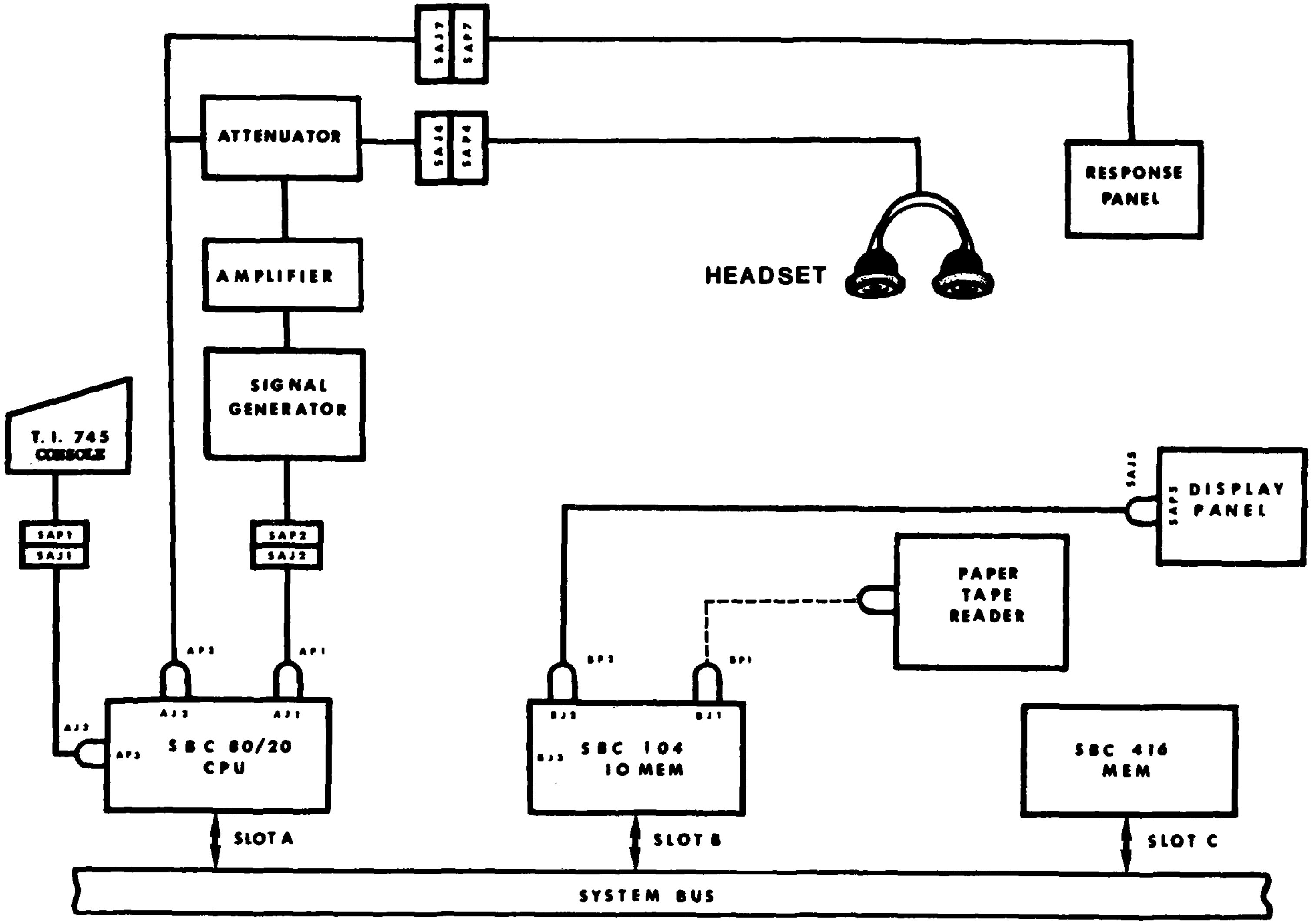


Figure 2. MPA hardware configuration.

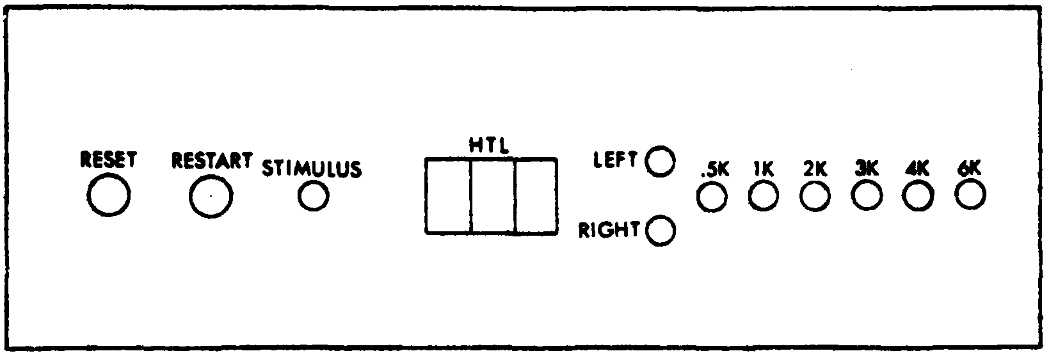


Figure 3. MPA display panel.

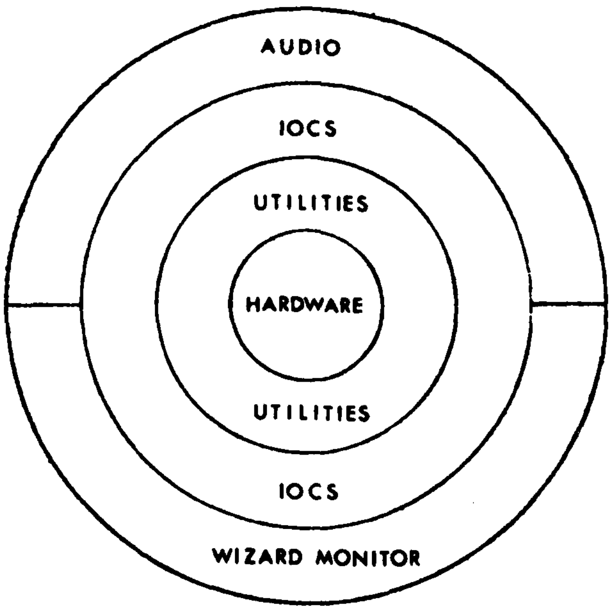


Figure 4. Software heirarchy diagram.

HARDWARE CONFIGURATION AND DETAILED OPERATION

The USAFSAM MPA consists of two relatively separate hardware elements: the microcomputer and the analog audiometer. First, the analog portion of the system will be described, with full details of each major functional element. Next, the microcomputer will be defined, with a thorough explanation given of each part.

Analog Audiometer

The sine-wave generator, digital-to-analog (D/A) convertor, pulse shaper, multiplier, amplifier, and attenuator make up the six major functional elements (Fig. 5) of the analog audiometer.

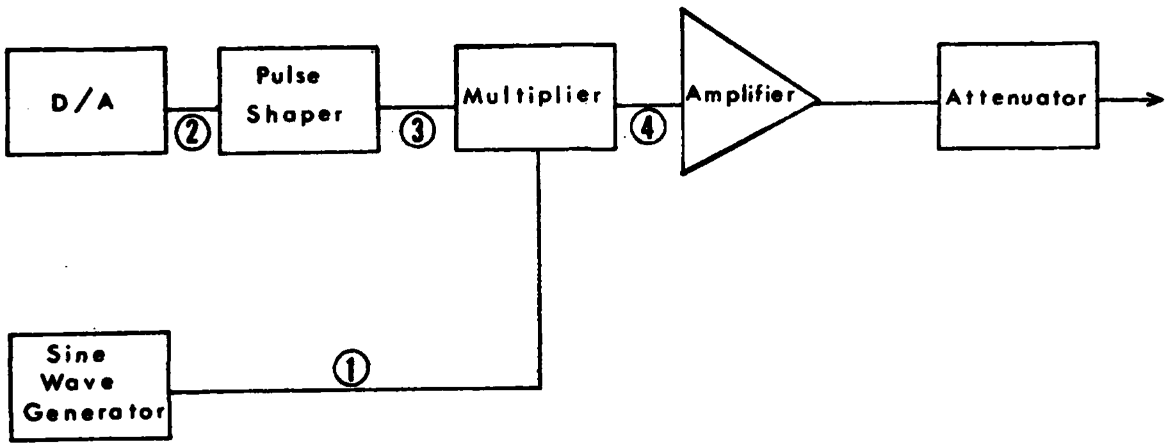


Figure 5. Analog subsystem: block diagram (numbers 1-4 correspond to wave shapes in Fig. 6).

Every time a tone output is required, the following process occurs:

a. The microcomputer sets the attenuator for the proper tone level and selects the left- or right-ear channel.

b. The microcomputer selects the proper frequency and enables the sine-wave generator to initiate waveform 1 (as shown in Fig. 6).

c. The microcomputer produces a calibrated voltage (waveform 2) by means of the D/A convertor.

d. The edge of the D/A voltage output pulse is smoothed by the pulse shaper to produce waveform 3.

e. Shaped waveform 3 and pulse sine wave 1 are multiplied to produce shaped sine-wave pulse 4.

f. The shaped sine-wave pulse is amplified by the power amplifier.

g. The amplified waveform is adjusted to the proper decibel (dB) level by the attenuator section and then output to the subject's headphone.

h. The microcomputer terminates the tone pulse by switching off the D/A convertor and sine-wave generator. The sine-wave generator is turned off 50 msec after the D/A convertor to allow for the decay of the shaped pulse.

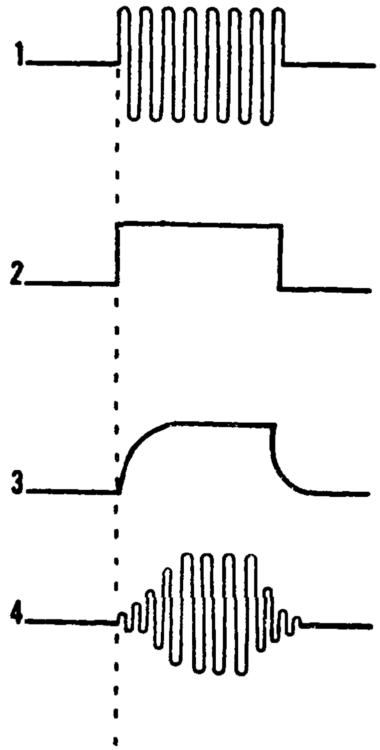
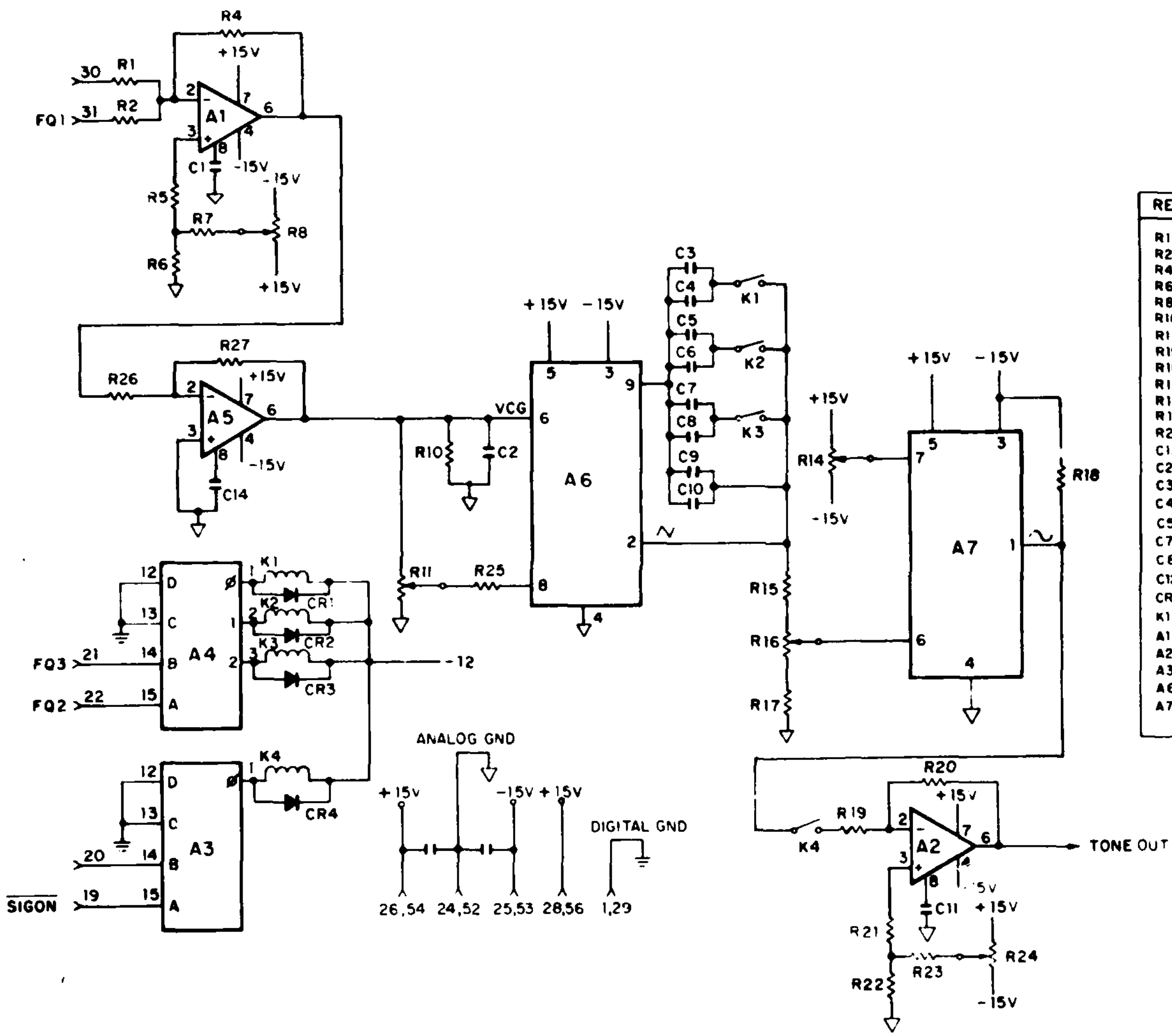


Figure 6. Analog subsystem waveshapes: 1--pulse sine wave; 2--calibrated voltage waveform; 3--shaped waveform; 4--shaped sine-wave pulse.

This 8-step process occurs every time a new tone is output to the subject's headphone. The nicest feature of the digitally controlled analog tone-generation system is that the entire tone-presentation procedure can be modified by the software without any change to the hardware elements.

The sine-wave generator (Fig. 7) consists of a Wavetek 120-021 voltage controlled triangle-wave generator and a Wavetek 120-022 triangle-to-sine-wave converter [8]. The Wavetek units and associated circuitry, shown in Figure 7, produce the required tones in the following manner:

a. The Wavetek generator provides two means of adjusting frequency: the voltage input on pin 6 and the capacitance attached between pins 2 and 9. By rigidly controlling the voltage on pin 6 at either 2 or 4 V and providing three switchable capacitor banks on the output, six distinct frequencies can be generated.



REFERENCE DESIGNATION	DESCRIPTION
R1, R7, R23	20K 1%
R2	21.5K 1%
R4, R5, R26, R27, R20, R21	10K 1%
R6, R22	10Ω 1%
R8, R24	20K POT
R10	10K 5%
R11, R14	100K POT
R15	130Ω 1%
R16	20Ω POT
R17	110Ω 1%
R18	2.2K 10%
R19	4.7K 5%
R25	330K 10%
C1, C11, C14	100pF
C2	.001μF
C3	.00102 μF
C4	.0003 & .00472 μF
C5	.00152 μF
C7	.00102 μF
C8	.00005 μF
C12, C13	100 μF
CR1, CR2, CR3, CR4, CR5, CR6	IN4148
K1, K2, K3, K4, K6	CLARE PRB 2513
A1, A5	LM308AH
A2	LM741CH
A3, A4	SN7445
A6	WAVETEK 120-021
A7	WAVETEK 120-022

Figure 7. Signal generator circuit.

b. The microcomputer then sets the required frequency with the use of three TTL-level control signals (FQ1, FQ2, and FQ3). First, FQ1 feeds through an adjustable 20-K resistor to the summing junction of A1. There, FQ1 is summed with a constant bias voltage applied through pin 30 and input to amplifier A1, which outputs the signal to inverting amp A5. A5 has unity gain and feeds the signal directly to the frequency-control pin of the Wavetek generator. Therefore, signal FQ1 can set 2 or 4 V on pin 6 of the Wavetek by going low and high respectively. This acts as a frequency-doubler control dividing the output frequencies into two groups: 500, 2000, and 3000 Hz and 1000, 4000, and 6000 Hz.

c. Signals FQ2 and FQ3 are input to A4 (an SN 7445 2 to 4 decoder), which selects relay K1, K2, or K3. As each relay is independently selected, a different output frequency is generated. The frequencies are set in accordance with Table 1.

d. The triangle-wave output from A6 is converted to a sine wave by A7; after which, relay K4 controls the output to amplifier A1. By the microcomputer activating-signal SIGON, the decoder A3 properly switches relay K4, thereby controlling the signal generator output.

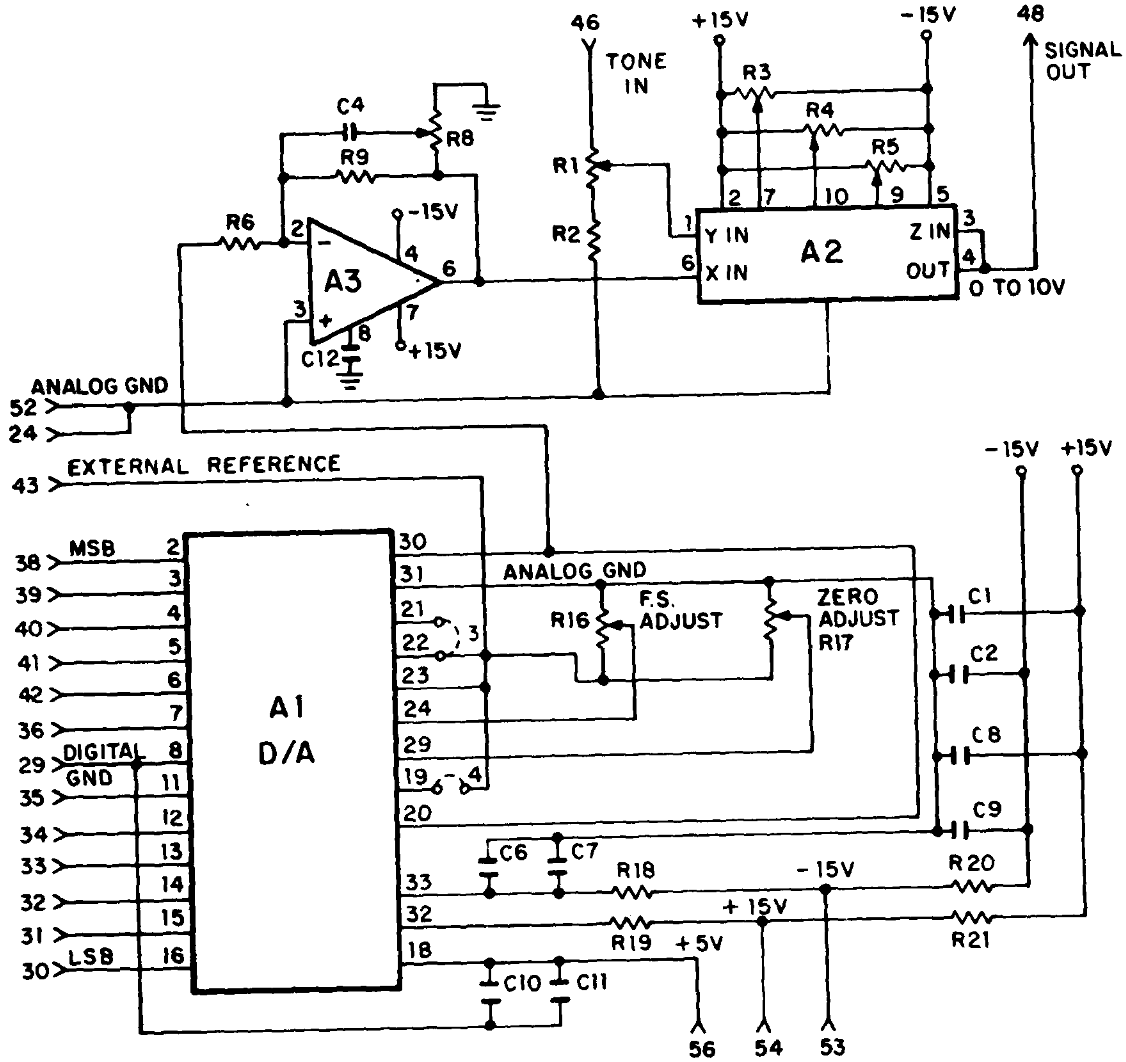
TABLE 1. FREQUENCY SELECT CONTROL SIGNALS

FQ3	FQ2	FQ1	Output frequency (Hz)
0	0	0	500
0	0	1	1000
0	1	0	2000
1	0	0	3000
0	1	1	4000
1	0	1	6000

After the signal-generator frequency has been set and the signal turned on, the D/A convertor must be set to output a calibrated DC-multiplier voltage. A 12-bit Zeltex D/A convertor (Fig. 8) allows the microcomputer to set the output voltage from 0 to 10.24 V in 2.5-mV steps. The zero and full-scale outputs can be adjusted by R17 and R16 respectively. The microcomputer uses the D/A convertor to produce an adjustable-voltage pulse which can be calibrated to fine-tune the output-tone dB level.

If the pulse from the D/A convertor was used directly to switch the tone-generator signal on and off, the sharp edges of the D/A pulse would cause harmonics in the resulting switched tone. By passing the D/A output through a first-order active filter, the harmonic-generation problem is alleviated. The filter consists of amplifier A3 and components R6, R8, R9, and C4, shown in Figure 8. Resistor R8 adjusts the filter time constant from 0 to 50 ms. After being properly shaped, the D/A pulse is fed to the multiplier.

The multiplier (Fig. 8) multiplies the calibrated shaped pulse with the sine wave to produce a calibrated tone signal. Three potentiometers (R3, R4, and R5) can be used to make the following adjustments: R3 to compensate for offset in the shaped pulse, R4 for offset in the sine wave, and R5 for



A1	ZELTEX ZD430
A2	AD530LH
A3	LM308AH
R1	5K POT
R2	4.75K 1%
R3,4,5	20K POT
R6,9	100K 1%
R8	1K POT
R16,17	10K POT
R18,19,20,21	10 Ω
C1,2	100 pF
C6,7,8,9	100 μF
C10	6.8 μF
C11	.01 μF
C12	.003 μF

Figure 8. D/A convertor and waveshaping circuit.

offset in the multiplier output. From the multiplier, the signal goes to the power amplifier (Fig. 9), which simply provides unity gain power amplification and impedance matching (100 ohm) for the signal prior to its output to the attenuator.

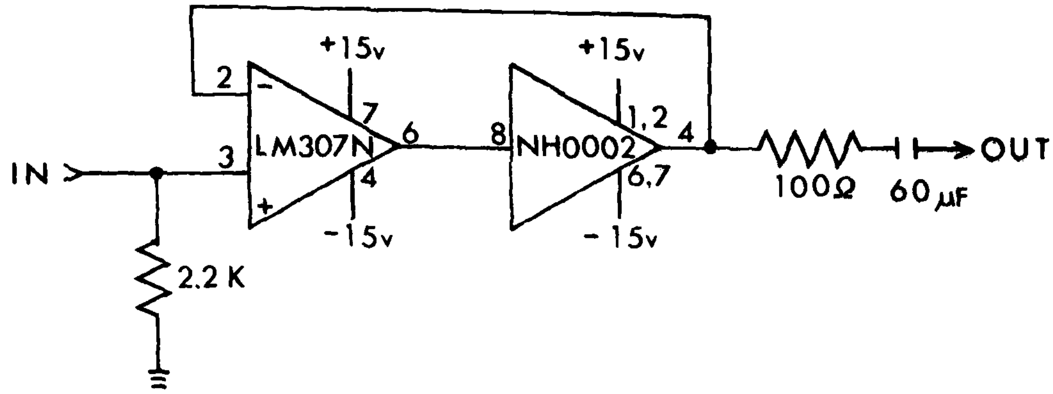


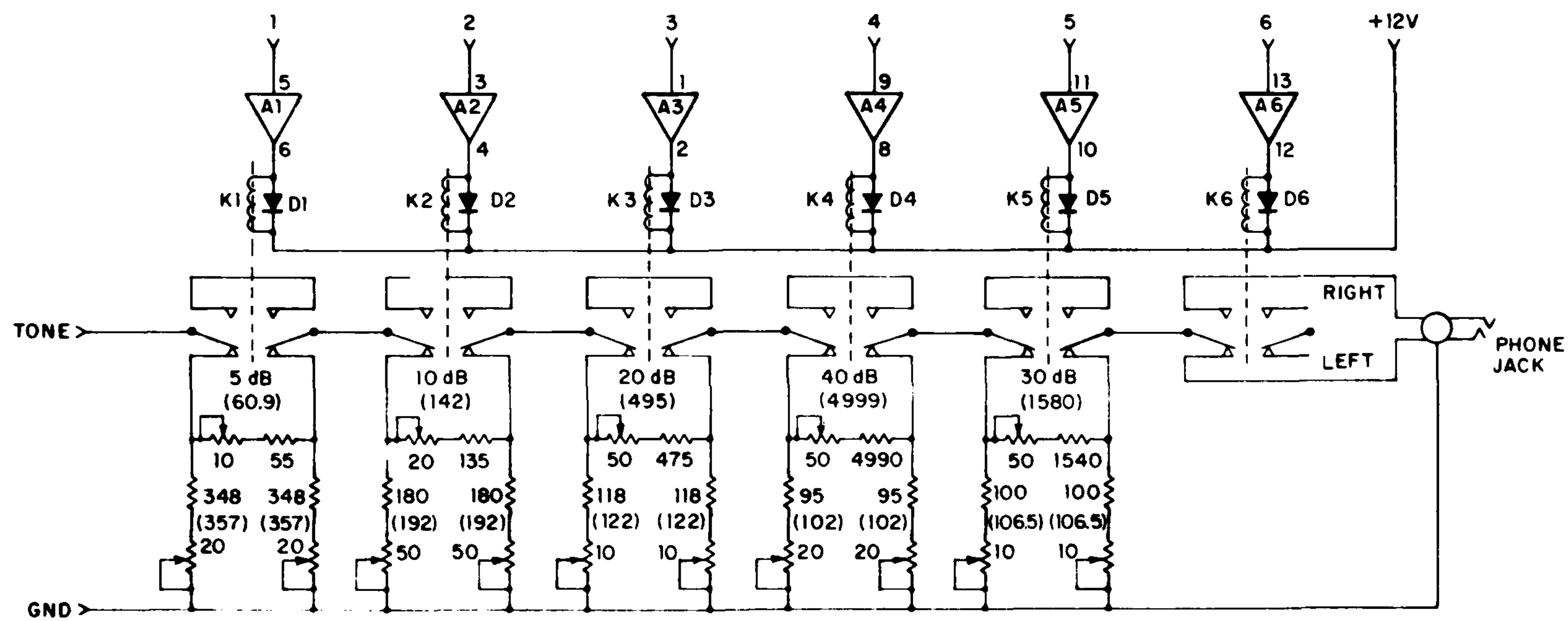
Figure 9. Power amplifier circuit.

The attenuator, shown in Figure 10, allows the microcomputer to attenuate the tone signal from 0 to 100 dB in 5-dB steps. It consists of five pi-type resistor pads which can be switched in or out with relays [1]. Each pi section is designed as a 100-ohm load so that each section can be switched in and out without changing the load on other sections. Relays K1, K2, K3, K4, and K5 provide switching for 5, 10, 20, 40, and 30 dB of attenuation respectively. Relay K6 switches the output between the left and right ears. The signal is then fed to a pair of TDH-39 earphones which complete the tone-generation path.

Microcomputer

The microcomputer houses three system-level computer boards (as indicated in Fig. 2). These boards provide maximum flexibility for system design as well as substantial surplus capability for future system expansion. Each board serves a unique function.

The SBC 80/20 single-board computer [5] provides the "brains" of the system, along with additional memory and I/O capability. In fact, the analog audiometer is controlled by the SBC 80/20. As indicated in Appendix A, Figure A-1, six parallel I/O ports are used to control the audiometer. The necessary board-level modifications for configuring the SBC 80/20 are shown in Table 2.



NOTE: VALUES SHOWN IN PARENTHESIS ARE CALCULATED VALUES FOR 100-OHM TRANSMISSION LINE WITH INDICATED LEVELS OF ATTENUATION

Figure 10. Attenuator circuit.

TABLE 2. SBC 80/20 BOARD MODIFICATIONS

Wire-Wrap Modifications

Function	Delete	Add
RAM location select	120-121	117-121
Cntr Ø to Cntr 1 (clock input)	141-142	141-143
Cntr 1 to IRØ (delay clock)	25-45	24-34
IR7 (no interrupt)	26-35	36-37-38-39-31
AACK enable		135-136
External Interrupt 1 (restart)		44-25

Driver/ Terminator Requirements

Socket	Driver/Terminator
A3	SN 7437
A4	SN 7437
A5	SN 7437
A6	SN 7437
A11	SBC 902
A12	SBC 902

One port, E4H, controls the audiometer frequency output--with signals FQ1, FQ2, and FQ3 (as indicated in Table 1). Ports E5H and E6H provide a 12-bit digital control word for the D/A convertor which serves as a gain control for the output tone, and port E8H uses five control lines for setting the required attenuator pads. A "table look-up" method is used for converting desired HTL settings into required attenuator control words. Port E9H serves a dual function: (1) the lower four bits contain the patient response, and (2) the upper two bits are reserved for a random-number generator input. The random number is derived from a free-running NE 555 timer, as indicated in Figure A-2. Finally, individual control lines for signal-on, ear-select, and lamp-select are provided through port EAH. All control signals are at TTL levels. The only remaining function of the SBC 80/20 is to provide a communications link to the operator's console (TI 745) which communicates via an RS 232C serial port set for 300 baud.

The remaining system control functions are provided on the SBC 104 memory and I/O board [6]. As was indicated in Figure 2, the SBC 104 accomplishes all I/O for the audiometer display panel and the paper tape reader. Six individual control bits (FRQØ-FRQ5, Fig. A-3) from port B8H activate individual front panel LEDs for indicating the frequency selected. Next, port B9H controls the 3-digit HTL indicator which can display any 5-dB level between Ø and 195 dB. The remaining three LEDs--for left ear, right ear, and stimulus present--are controlled from port BAH. An additional capability for design-laboratory use allows a paper tape reader to be used if required. This provides an extremely beneficial tool for loading preliminary software into temporary RAM for evaluation prior to making the code permanent in PROM. Ports B6H and B7H provide the necessary control and data line for complete operation of the paper tape reader. All SBC 104 wire wrap and other board modifications necessary are shown in Table 3.

TABLE 3. SBC 104 BOARD MODIFICATIONS

Wire-Wrap Modifications

Function	Delete	Add
I/O address select (BOH-BFH)	S2 1-4	S2 1-6
Baud-rate select (300 baud)	S1 1-4	S2 1-9
External interrupt 1 (restart)	27-28	26-27

Memory Select Switches

Function	Position
RAM address select (8000H-8FFFH)	S3 SW-1 OFF
PROM address select (1000-1FFFH)	S4 SW-2 OFF

Driver/Terminator Requirements

Socket	Driver Terminator
A3	SN 7437
A4	SBC 902
A5	SBC 902
A6	SBC 902
A7	SBC 902
A10	SN 7438
A11	SN 7408
A12	SN 7408

The SBC 416 board [7] gives the microcomputer 16-K-byte PROM space for additional program storage. At present, only 8K of the available space has been used, leaving much room for future expansion. Necessary SBC 416 board configuration parameters are provided in Table 4 for reference.

TABLE 4. SBC 416 BOARD MODIFICATIONS

Function	Switch Setting
PROM select (Block X)	(S1) SW1-SW10 ON
PROM select (Block Y)	(S2) SW1-SW10 ON
BIAS ADD select (Block X)(4000H)	X1=Ø, X2=1, X3=Ø
BIAS ADD select (Block Y)(6000H)	Y1=1, Y2=1, Y3=Ø
ACCESS time code	(S3) SW3 ON; SW1, SW2, SW4 OFF

SOFTWARE CONFIGURATION AND OPERATION

The SAM MPA contains two major software packages which operate concurrently. The WIZARD operating system [3,4] provides most utilities and system-control features, while the AUDIO programs support all aspects of the audiometric test. Figure 11 shows where all the systems and applications software reside within the 64-K-byte maximum memory space and also breaks down the availability of RAM and PROM on each computer board.

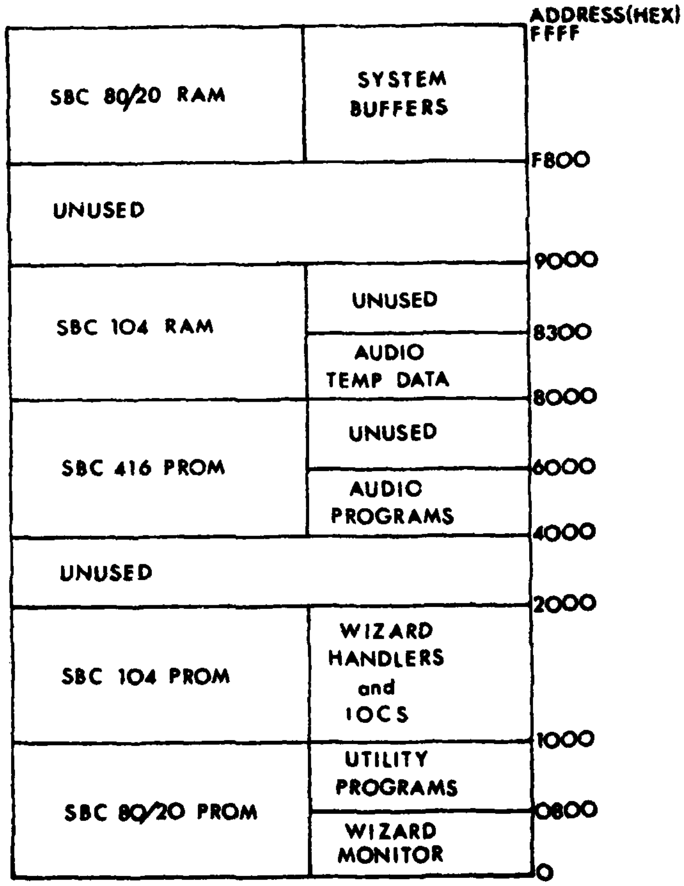


Figure 11. MPA memory map.

Under normal circumstances, the WIZARD operating system remains totally transparent to the audiometric technician. Upon power-up, the MPA automatically executes the AUDIO software and shows no indication of the system software. Once in the command decoder, the operator can access WIZARD by entering "WIZARD" as a command and pressing the carriage return. Details concerning the operation of the system under WIZARD will be discussed in the System Operation section.

The entire AUDIO software package was designed in a totally modular fashion as indicated in Figure 12. All modules shown in the software structure chart are executed from left to right; e.g., SYSNIT is the first module executed under AUDIO. As indicated, SYSNIT, in turn, calls upon four other modules to complete all system-initialization functions.

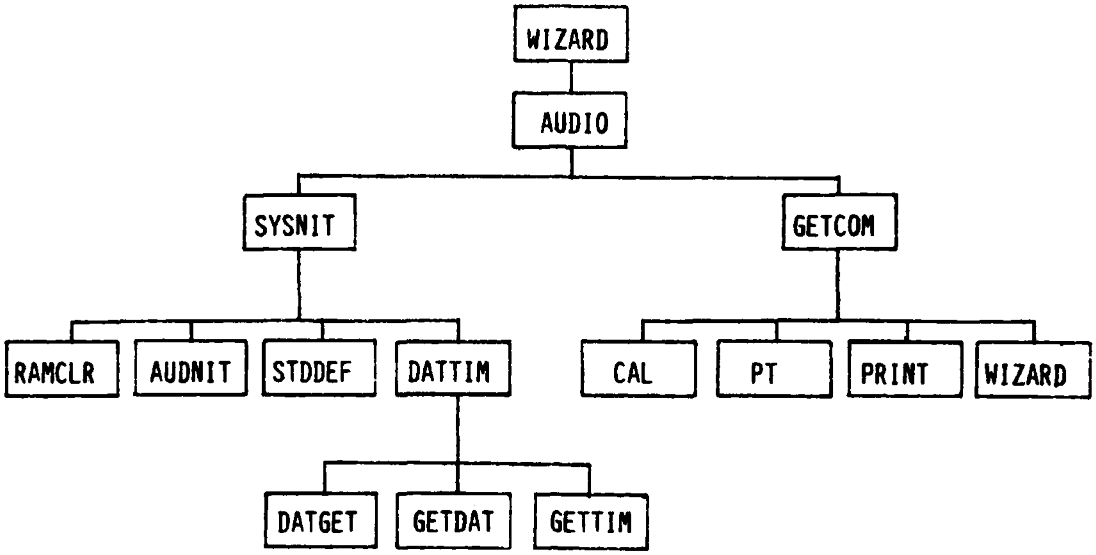


Figure 12. AUDIO software structure chart.

The first initialization routine, RAMCLR, clears out all storage space to ensure that no erroneous data show up in the test results. The second, AUDNIT, initializes all tables and hardware devices. This includes the programming of peripheral interface circuits that are directly subordinate to the audiometer, such as the frequency and attenuator control lines. Next, STDDEF sets all program defaults in case any kind of system reconfiguration has been made possible. Currently, STDDEF is a dummy module and not used. The last SYSNIT subordinate module, DATTIM, requires the operator to provide the current date. In turn, this date is printed out on each patient record to indicate the date of the test. The realtime clock was not implemented on this machine; therefore, the GETTIM module is nonoperational.

After SYSNIT, the MPA enters the command decoder and prompts the operator for a command. As indicated in Figure 12, there are four possible commands the operator can enter: CAL, PT, PRINT, and WIZARD. The actual execution of these modules will be explained later, but the programs themselves will be described here.

As implied by the name, CAL allows the operator to perform manual testing and calibration of the audiometer. As shown in Figure 13, subordinate modules TONCAL and MANCAL can be executed once CAL has been selected. Each of these modules in turn use all the driver routines available through AUDDRV to accomplish control functions with the audiometer. The MANCAL module gives the operator complete flexibility in selecting left or right ear, HTL, frequency, and signal on and off.

The most important software module, PTTEST, performs all necessary test and analysis functions related to the audiogram. Figure 14 shows that PTTEST breaks down into four major subgroups: PTNIT, COLDAT, PTANAL, and PTDISP. The first to be executed, PTNIT, collects all patient identification information from the operator. Such items as name, SSAN, and date-of-birth are collected with this routine; the reference audiogram is also entered at this time

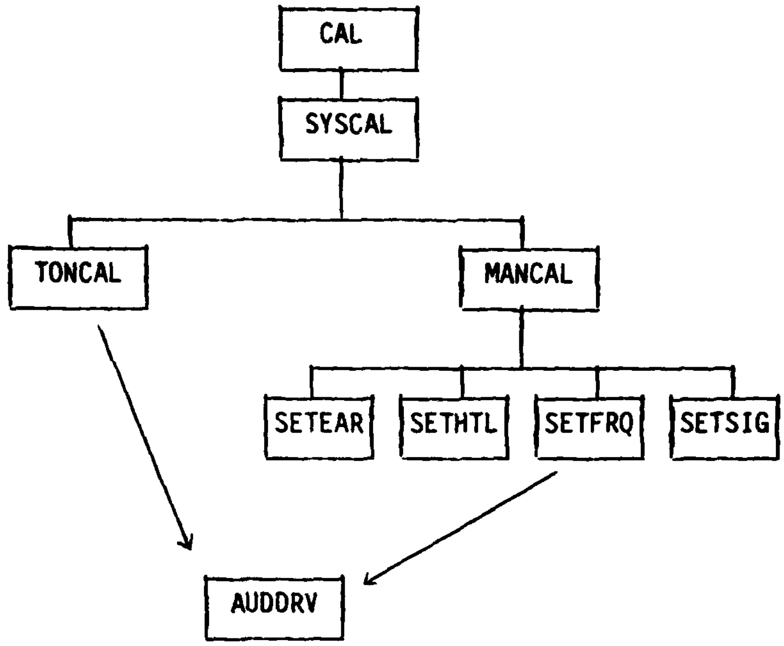


Figure 13. Calibration software structure chart.

as required. Next, COLDAT performs an entire tone-count audiometric test and stores all the results in RAM. PTANAL then takes the test results and calculates all threshold shifts, based on the reference audiogram. Finally, PTDISP computes if any significant threshold shifts have occured and stores the test results along with the required disposition for display to the operator by the PRINT routine, which is executed next. After the data have been output on the console, the MPA returns to the command decoder.

The remaining two options are PRINT and WIZARD. If the operator requires multiple copies of the test results, he can successively enter "PRINT" to get the copies required. "WIZARD" is used exclusively for debugging purposes and is not executed under normal system operation.

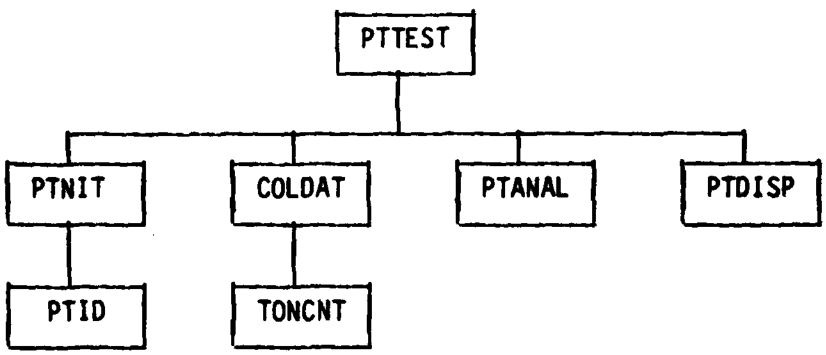


Figure 14. Patient-test software structure chart.

SYSTEM OPERATION

The operation of the SAM MPA was designed for maximum simplicity with an allowable amount of flexibility. This was accomplished by providing a command decoder at the highest level of operation for flexibility, and then substituting menu-select techniques during the patient-test phase. Each of these aspects of the MPA will become more evident as the discussion of system operation progresses.

After power-up, the operator receives a request on the console for the date. This information must be entered in the following format: YY/MM/DD (e.g., 79/10/30). When complete, the date is echoed back to the operator in the conventional format: day month year (e.g., 30 October 1979). The operator is then given the choice of reentering the date in the case of an error or proceeding to the next phase. By reformatting the date before echoing, the MPA provides the operator an exceptional means of picking up any simple typographical errors. A lengthy error-checking software procedure ensures that no illegal date entries are accepted.

Next, the AUDIO command decoder prompts the operator with an asterisk (*) for command entry. The four possible commands at this point are PT, CAL, PRINT, and WIZARD.

The PT command vectors the operator into the audiometric test program, at which time the system switches to menu select as shown below and requests the operator to select the purpose of test:

```
SELECT PURPOSE OF TEST
A.  REFERENCE
B.  ANNUAL
C.  90-DAY
D.  15-HOUR
E.  40-HOUR
F.  30-DAY FOLLOW-UP
G.  MONTHLY No. 2
H.  MONTHLY No. 3
I.  MONTHLY No. 4
J.  MONTHLY No. 5
K.  CLOSE SCRUTINY
L.  TERMINATION
```

The MPA requires this information to determine the test procedures and criteria pertinent for the patient. Figure 15 shows the multiple audiograms given in the evaluation phase of the HCP. Once the purpose of the test has been selected, the operator must enter patient-identification information as requested, along with reference audiogram data if needed. Each identification parameter is uniquely requested, thereby leaving no room for error and/or loss of data integrity. At this point, the MPA prompts the operator with START THE TONE COUNT TEST (Y or N)? A Y answer immediately places the machine in the test mode and starts the tone-count audiometric test. (Details regarding the

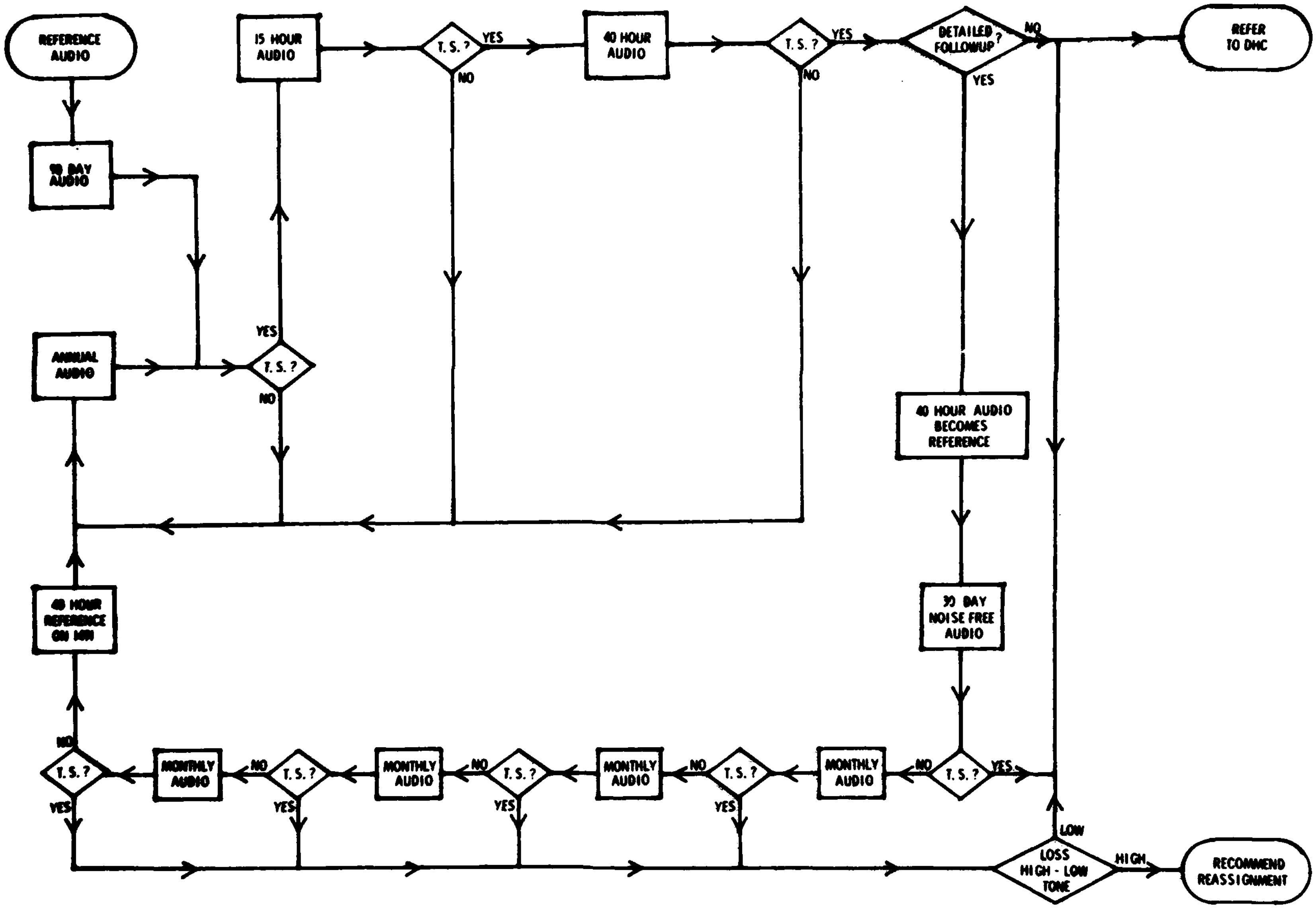


Figure 15. Hearing Conservation Program testing sequence.

specifics of the tone-count test procedure and how it compares to manual audiometry can be found in References 1 and 2 respectively.) On the other hand, an N input vectors the MPA back to the AUDIO command decoder. During the tone-count test, the operator is limited to three possible control actions:

(1) placing the test in a pause condition by entering CNTL S on the keyboard and continuing the test by entering CNTL Q,

(2) initiating a test restart back to the start of the tone-count test by pressing the restart switch, or

(3) reinitializing the entire system by pressing the reset switch.

These operations provide the operator some functional control during the automatic test phase when the machine functions independently. During the test, the operator is provided sufficient feedback via the front panel display to determine whether the test is progressing successfully. When the patient completes the test, the operator is asked if a printout of test results is desired. A Y answer initiates a complete printout as shown in Figure 16, whereas an N input vectors the machine back to the AUDIO command decoder. Once back at the command level, the PRINT command can be usea to obtain additional copies of the test results. If the tone-count audiometric test was not executed and the command to print the test results is entered, the MPA will output meaningless data and will require resetting before any further action can be taken.

123-45-6789 DOE JOHN D. DOB 1 JAN 1940

BROOKS AFB TEXAS ZIP 78235

PURPOSE FOR TEST: ANNUAL

DATE OF AUDIO: 30 JAN 1979

LEFT EAR						RIGHT EAR					
500	1000	2000	3000	4000	6000	500	1000	2000	3000	4000	6000
0	5	10	10	15	20	5	10	10	20	25	35

DATE OF REFERENCE: 1 JAN 1959

0	0	5	5	10	10	0	5	5	10	10	10

THRESHOLD SHIFT

0	5	5	5	5	10	5	5	5	10	15	25

DISPOSITION

STS 15 HOUR

Figure 16. Sample test-results printout.

The CAL command permits the operator to perform an analog adjustment of the tone levels as well as select the HTL, frequency, left or right ear, and on or off signal. This provides maximum flexibility in testing the system under laboratory conditions. The automatic calibration feature allows the audiometer to be fine-tuned to provide the necessary tone intensity at each frequency. Twelve 12-bit words, used to control the output of the D/A convertor, are stored in PROM and act as digital calibration values. During calibration, these values are transferred to RAM and are varied with the use of the patient response-panel switches until the desired reading on the sound-pressure meter is reached. Switch 1 increases the sound level, switch 2 decreases the level, and switch 3 changes the output to the next higher frequency. Each earphone is calibrated separately for six frequencies. Once all the digital values are known, they are output on the console for verification. The operator must then have the new values (located in the software module MULTAB, which is grouped with the AUDDRV routines) programmed in PROM and have the old values deleted.

The operator is also given a completely manual control capability over the machine. In many instances it is desirable to select a specific HTL and frequency for electronic adjustment. When the manual select option under CAL is chosen, a new prompt, a ?, is presented. The operator can then issue the commands listed in Table 5, as desired. (Table 5 has been included as a shorthand reference to all commands the MPA will accept.) When complete, the EXIT command can be used to return the machine to the AUDIO command decoder.

TABLE 5. MPA COMMAND SUMMARY

Prompt	Valid Command	Function
*	PT	Start patient test
*	CAL	Perform calibration
*	PRINT	Print test results
*	WIZARD	Vector to operating system
?	SH=(Ø to 1Ø5)	Set HTL
?	SF=(.5,1,2,3,4,6)	Set frequency
?	LEFT	Select left ear
?	RIGHT	Select right ear
?	ON	Turn signal on
?	OFF	Turn signal off
?	EXIT	Return to AUDIO
Valid during audiometric test only:		
None	CNTL S	Pause audiometric test
None	CNTL Q	Continue audiometric test
Valid during any data entry:		
None	RUBOUT	Delete one character
None	CNTL X	Delete previous line

The last AUDIO command, WIZARD, is used only by programmer personnel. This command provides a means of entering the operating-system command decoder or monitor to: substitute memory values; input and output byte values to known I/O ports; display memory; display CPU registers; and vector control to known memory locations.

DISCUSSION

The USAFSAM MPA provides audiology personnel with the mechanism to investigate various aspects of automatic audiometry. The ability to change the test algorithm, along with all HCP decision criteria, stands as the single most valued feature of this instrument. Due to its extensive flexibility, this instrument will remain adaptable to future concepts, thereby providing a tool for future research. A contract for six similar devices was released in July 1979 to advance this project to the field testing phase. We anticipate that the future implementation of comparable instruments will become a cornerstone of the Air Force Hearing Conservation Program.

REFERENCES

1. Meyer, C. R., et al. The tone-count audiometric computer. SAM-TR-75-50, Dec 1975.

2. Sutherland, H. C., Jr., et al. Comparison of TCAC and manual audiometry. SAM-TR-77-8, Apr 1977.

3. Wilson, S. D., et al., WIZARD: A string-oriented microprocessor operating system. SAM-TR-79-14, Aug 1979.

4. Wilson, S. D., and M. E. Womble. WIZARD programmer manual. SAM-TR-79-15, Sep 1979.

5. Intel Corporation. SBC 80/20 single board computer hardware reference manual. Document No. 98-317B, 1977.

6. Intel Corporation. SBC 104 combination memory and I/O expansion board hardware reference manual. Document No. 98-277, 1976.

7. Intel Corporation. SBC 416 16K PROM/RAM expansion board hardware reference manual. Document No. 98-256A, 1976.

8. Wavetek. Modular generators applications. Applications Note No. 120-1, Sep 1970.

APPENDIX A

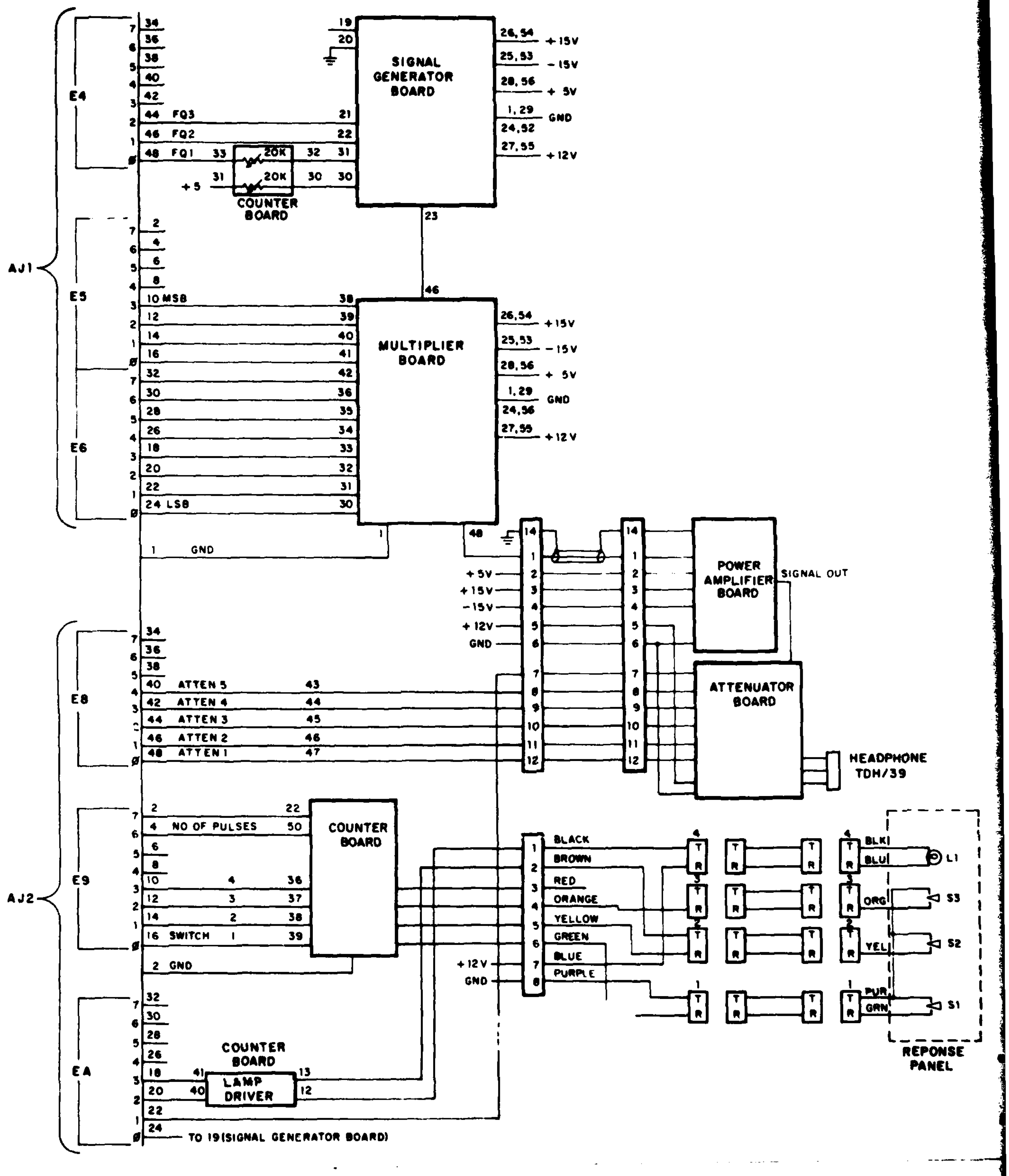
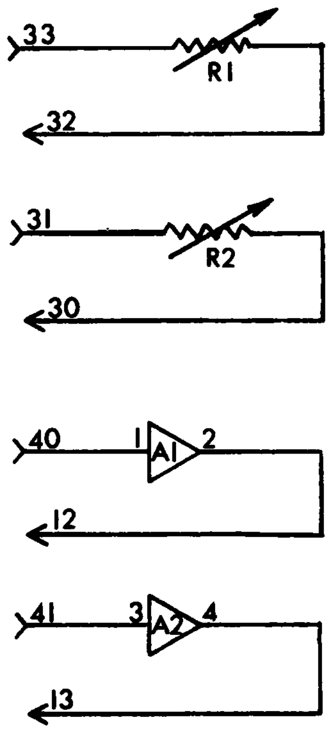


Figure A-1. SBC 80/20 control diagram.



PART #	DESCRIPTION
R1,R2	20K POT
R3,R4	15K
C1	.047 μF
A1,A2	SN7406
A3	NE555
A4	SN74LS93

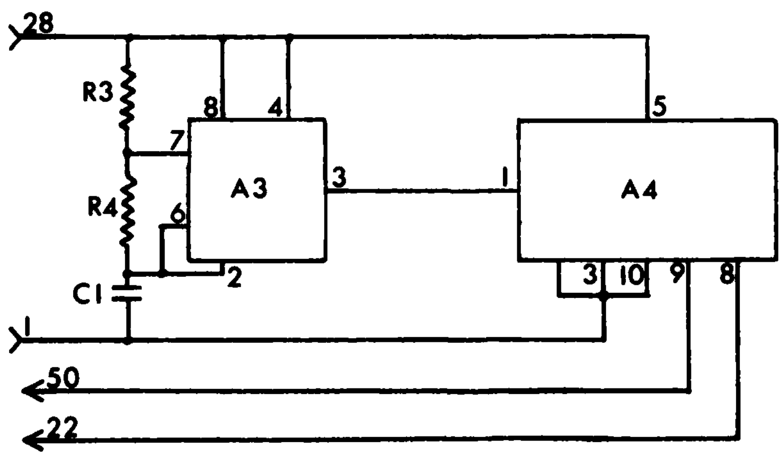
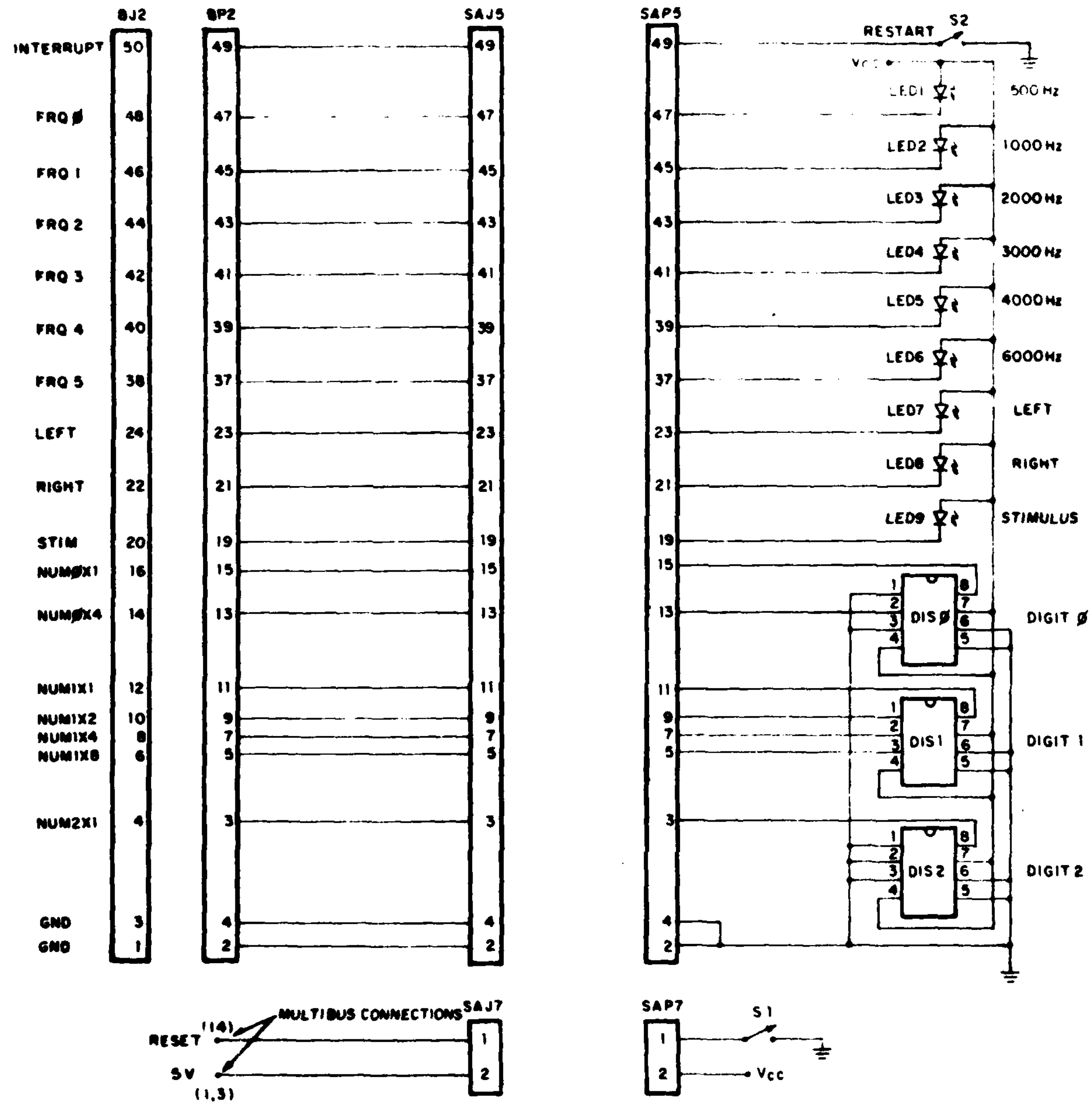


Figure A-2. Counter-board schematic.



ITEM	PART NO.	MFG
LED1-LED9	5082-4860	HEWLETT PACKARD
DIS0-DIS2	5082-7302	HEWLETT PACKARD

Figure A-3. SBC 104 control diagram and display panel schematic.